Start

101 — Generate a set of multi-level screens

102 — Screen the input digital image with the generated multi-level screens using a dither matrix and a set of level matrices

103 — For each of a select number of pixel locations in the input digital image, select one of the level matrices, based on the message symbol to be embedded at that pixel location, to create an output

End

Fig. 1

$$D = [d_{ij}] = \begin{bmatrix} d_{11} & d_{12} & \cdots & d_{1n} \\ d_{21} & d_{22} & \cdots & d_{2n} \\ \cdot & \cdot & \cdots & \cdot \\ \cdot & \cdot & \cdots & \cdot \\ d_{n1} & d_{n2} & \cdots & d_{nn} \end{bmatrix}$$

21

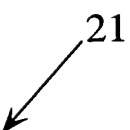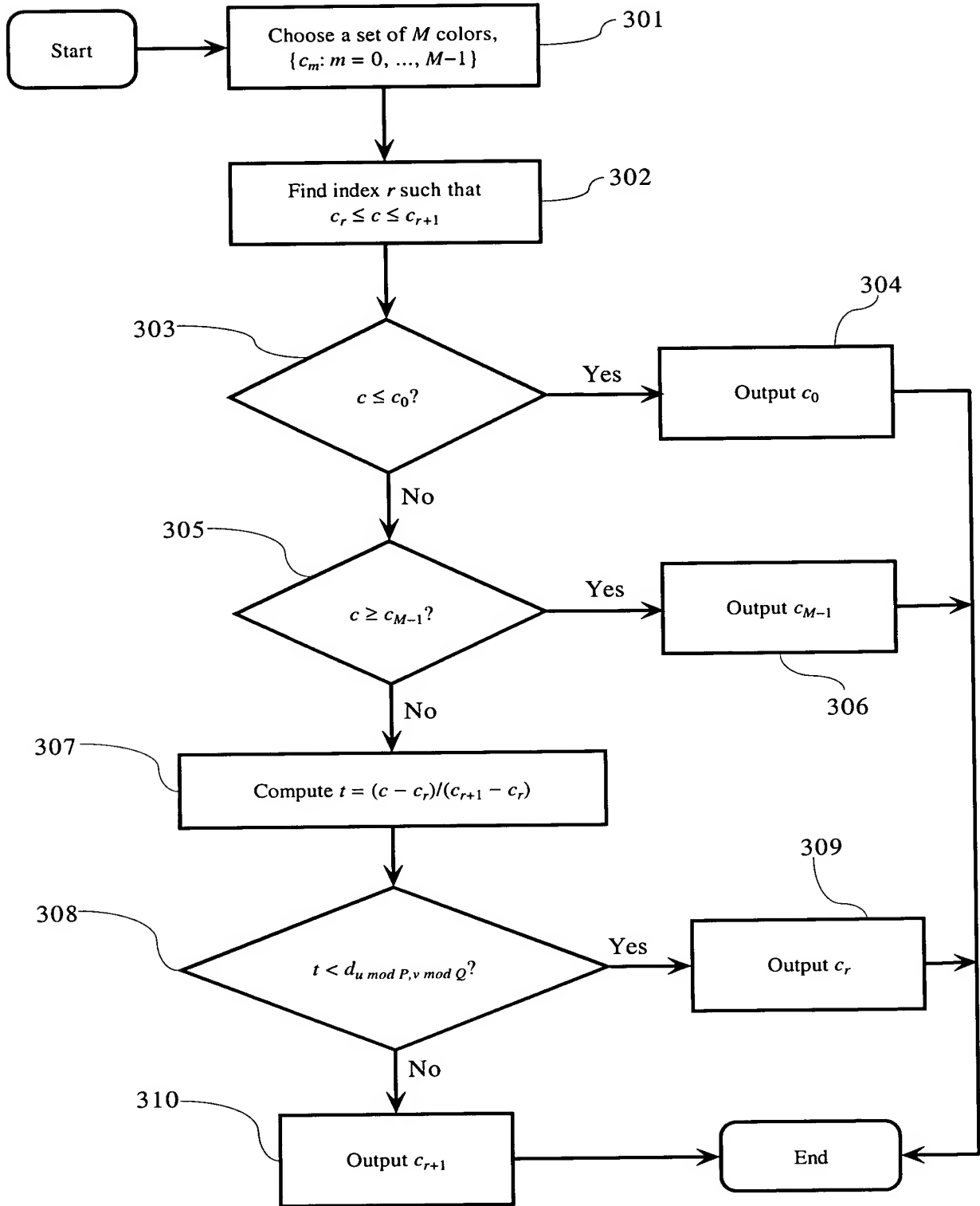**Fig. 2**

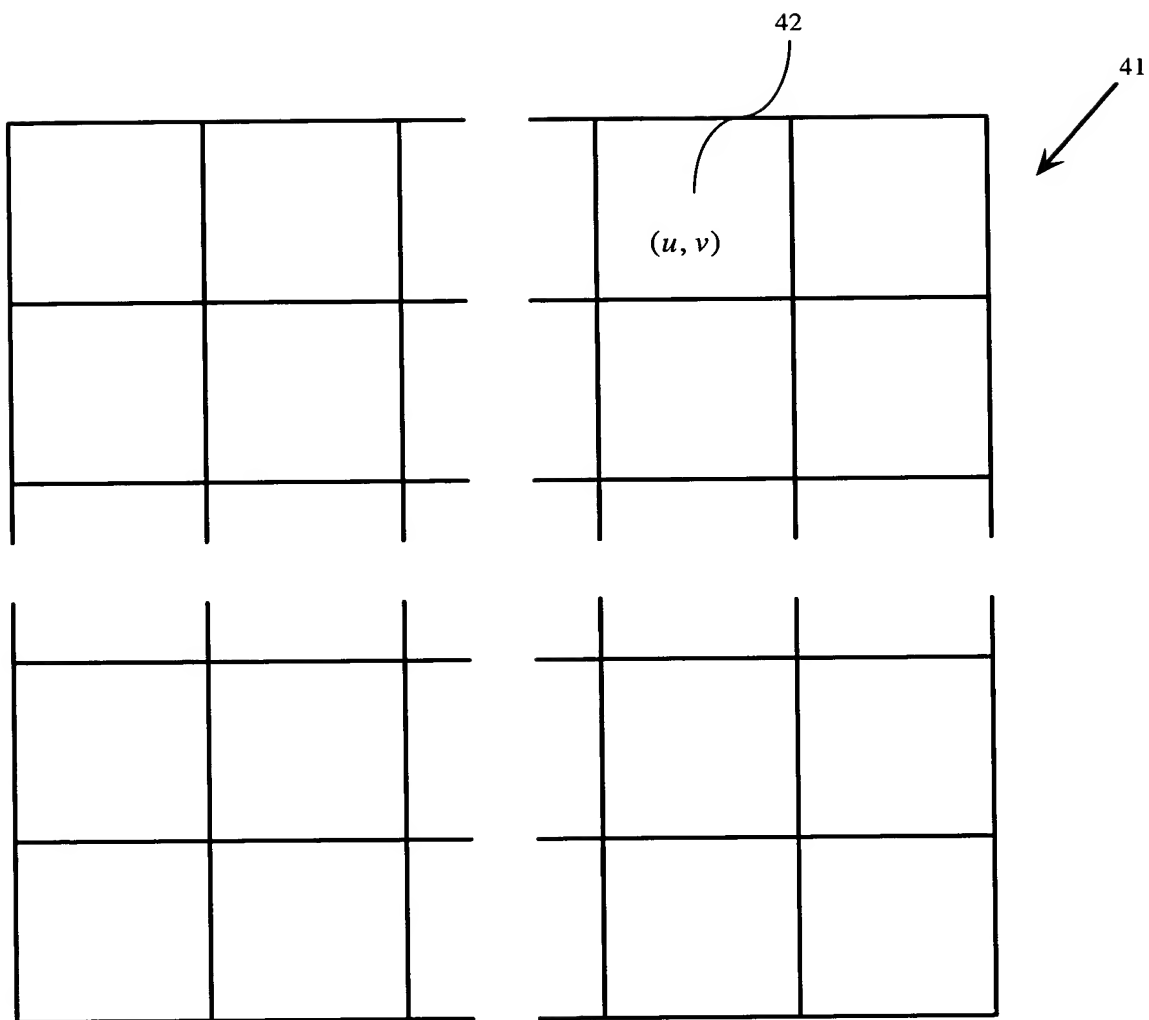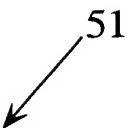Start → Choose a set of M colors, $\{c_m: m = 0, ..., M-1\}$ — 301

Find index r such that $c_r \leq c \leq c_{r+1}$ — 302

303 — $c \leq c_0$?

Yes → Output c_0 — 304

No

305 — $c \geq c_{M-1}$?

Yes → Output c_{M-1} — 306

No

307 — Compute $t = (c - c_r)/(c_{r+1} - c_r)$

308 — $t < d_{u \bmod P, v \bmod Q}$?

Yes → Output c_r — 309

No

310 — Output c_{r+1} → End

Fig. 3

42

41

(u, v)

Fig. 4

$$C^i = \{c_m^i : m = 0, ..., M-1\} = \begin{cases} [c_0^0 & c_1^0 & \cdots & c_{M-1}^0] \\ [c_0^1 & c_1^1 & \cdots & c_{M-1}^1] \\ [\ \cdot & \cdot & \cdots & \cdot\ ] \\ [\ \cdot & \cdot & \cdots & \cdot\ ] \\ [c_0^N & c_1^N & \cdots & c_{M-1}^N] \end{cases}$$

51

Fig. 5

C^1 61

$$C^1 \quad 0 \xrightarrow{\hspace{6cm}} 1 \longrightarrow \text{Output}$$

$c_0{}^1 \qquad c_1{}^1 \qquad c_2{}^1$

$$C^2 \quad 0 \xrightarrow{\hspace{6cm}} 1 \longrightarrow \text{Output}$$

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$c_0{}^2 \qquad c_1{}^2 \qquad c_2{}^2$
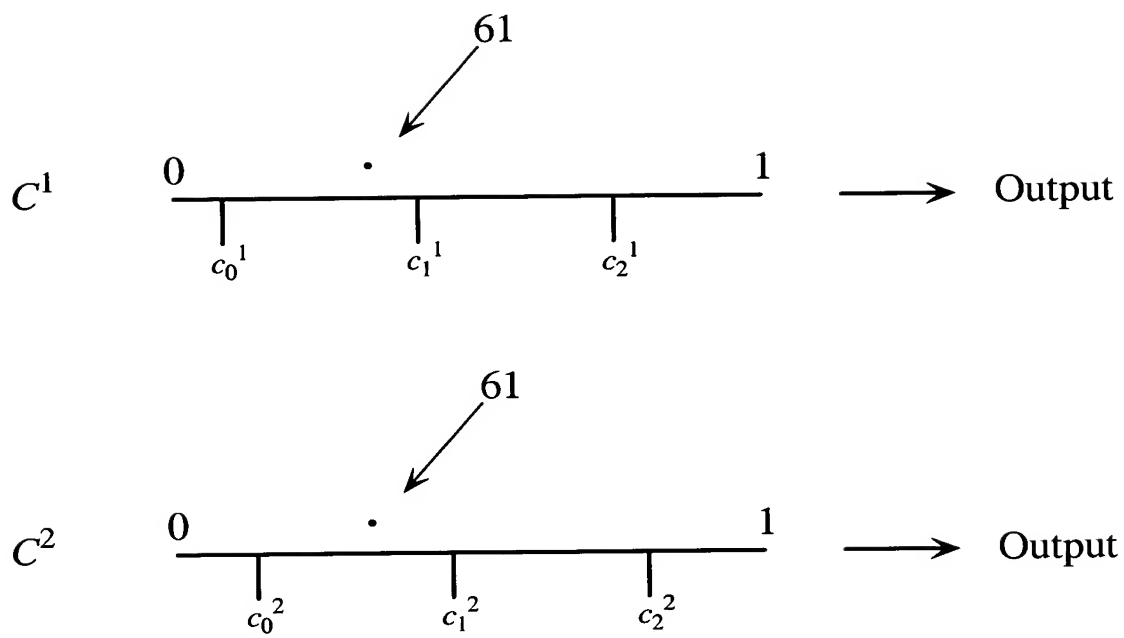
Fig. 6

$$C^i = \begin{cases} C^0 = [\quad 0 \qquad 4/255 \qquad 8/255 \qquad \cdots \qquad 252/255] \\ \\ C^1 = [1/255 \qquad 5/255 \qquad 9/255 \qquad \cdots \qquad 253/255] \\ \\ C^2 = [2/255 \qquad 6/255 \qquad 10/255 \qquad \cdots \qquad 254/255] \\ \\ C^3 = [3/255 \qquad 7/255 \qquad 11/255 \qquad \cdots \qquad 1] \end{cases}$$

Fig. 7

74	76	78	81	83
Input Device(s)	Scanner	Storage Device(s)	Display(s)	Printer

Input Controller	Controller	Storage Controller	Display Controller	Printer Controller

75   77   79

73   86   82

CPU

84

Comm. Controller

System Memory

71

85 —— Comm. Device

72

70

Fig. 8